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ABSTRACT

Context-aware systems are applications that adapt themselves to several situations involving user, network, data, hardware and the application itself. In this paper, we review several context models proposed in different domains: content adaptation, service adaptation, information retrieval, etc. The purpose of this review is to expose the representation of this notion semantically. According to this, we propose a framework that analyzes and compares different context models. Such a framework intends helping understanding and analyzing of such models, and consequently the definition of new ones. This framework is based on the fact that context-aware systems use context models in order to formalize and limit the notion of context and that relevant information differs from a domain to another and depends on the effective use of this information. Based on this framework, we consider in this paper a particular application domain, Business Processes, in which the notion of context remains unexplored, although it is required for flexibility and adaptability. We propose, in this paper, an ontology-based context model focusing on this particular domain.

Categories and Subject Descriptors

H.1.0 [**Information Systems**]: Models and Principles – *General*.
H.4.0 [**Information Systems**]: Information Systems Applications – *General*.

General Terms

Management, Design.

Keywords

Context-aware computing, context modeling, businesses process, ontology.

1. INTRODUCTION

In pervasive scenarios, mobile users need an informational content that suits their current context of use, which provides a description of the (changing) conditions (temporal, spatial, hardware, physical and environmental) under which a user accesses one or more services [6]. Such adaptation needs guided the proposition of context-aware systems. One of the core premises of such systems is that they should know about the *user's context* and they should be capable to react to any interaction in accordance with these circumstances [19]. Context-aware systems aim at automatically personalizing user's environment depending on the user's context, and hence, minimizing user interaction with the system and the invoked services.

In such systems, the notion of context plays a central role. It guides adaptation mechanism used to personalize content and services accordingly. The way context information is used in these systems depends on what information is observed and how it is represented. In other terms, the adaptation capabilities of a context-aware system depend on the context model used on it. Hence, a well designed context model is the cornerstone of a context-aware system [25]. Obviously, the formalism chosen for representing this model is important since it determines the reasoning methods the system can use to perform some adaptation. Through the literature, one can observe that many context models and representation approaches have been proposed by the context-awareness research community. They symbolize different viewpoints of the notion of context which have been investigated in different context-aware application domains (*e.g.* ambient intelligence, mobile tourism systems). A context model ensures the definition of independent adaptation processes and isolates this process from the context acquiring techniques, representing in this way the first requirement for the maintenance and evolution of context-aware systems.

The evolution of context-aware systems in the last decade has been followed by an important evolution on context models, varying from simple key-value structures to ontology-based models. The latter propose a semantic modeling of context information, enhanced by appropriate reasoning mechanisms. However, before considering the semantic modeling and use of context information, we should have a clear idea about the notion of context and its usage. Actually, several definitions [3] [9] [25], corresponding to different points of view, fields or goals, coexist. Initial researches on context-aware computing propose a limited view and use of this notion. Schilit and Theimer [24], for example, refer to context as "*the location, identity of nearby people and objects, and changes to those objects*". They claim that the important aspects of context are: where you are, who you are with, and what resources are nearby. Brown *et al*. [3] consider that the user's context represents his location, his nearby persons and time.

These first researches focused on the elements describing the context of use of a system rather than understanding its meaning. However, in the last years, more attention has been given to the real meaning of context, particularly for the context-aware systems. According to Dey [9], to use context effectively, we must understand what context is (the choice of which context elements require observation in an application) and how it can be used (what context-aware behaviors must be supported by this application). This author advocates that previous definitions of context were too specific since it is impossible to enumerate which aspects are important for all situations, as these will change from a situation to another.

Dey [9] defines the context as "*any information that can be used to characterize the situation of an entity*. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves". This definition of context can be used in any application scenario while specifying and enumerating the context characteristics. Another definition is given by Moran and Dourish [10], which state that "*context refers to the physical and social situation in which computational devices are embedded*".

However, such definitions remain general and reveal an important issue: the identification of the elements composing the notion of context. According to Chaari *et al* [7], the definition given by Dey does not distinguish context data from application data. These authors consider that this separation is very important for the context modeling. According to these authors [7], the context is a set of parameters which are extern to the application and that influence the behavior of the application. It describes the user situation in terms of location, time, environment, terminal, user's profile, etc. The definitions above show that the notion of context may refer to many different concepts that vary according to the application domain in which this notion is applied, as well as how they are used by the applications. Consequently, it is often difficult to evaluate and compare different context models. Moreover, new application domains are starting to use the notion of context, leading to the development of new context models, appropriate to these domains needs.

In this paper, we present a review of several context models proposed in different application domains in order to semantically represent this important notion. Based on this review, we propose a framework for analyzing such models. On the one hand, this framework intends to guide readers in their analysis and understanding of such context models. On the other hand, by helping the understanding of such models, this framework ought to contribute to the development of new ones. Last but not least, this paper considers a particular application domain, Business Processes (BP) engineering and enactment, in which the notion of context remains mainly unexplored, although it is needed for flexibility and adaptability requirements. We propose, in this paper, an ontology-based context model focusing on this particular domain.

The reminder of this paper is structured as follows. Section 2 introduces a state of the art on context modeling. In section 3, we analyze this state of the art and propose the analysis framework. In section 4, we introduce the proposed context model for BP area called CM4BP. Section 5 presents our conclusions and perspectives.

2. RELATED WORKS ON CONTEXT MODELING

In the last years, context models were subject of several researches, particularly on context-aware computing, in which different approaches for context modeling were proposed. Strang *et al.* [25] pointed out most relevant ones. These authors classified models according to data structures used to maintain and to exchange contextual information in a given system. The first and simplest model is the *Key-Value pairs*. Although such models are easy to manage, they lack capabilities for sophisticated structuring and for enabling efficient context retrieval algorithms.

A second approach pointed out by Strang *et al.* [25] is the approach using *Markup scheme models*. Such models represent context information in a hierarchical data structure consisting of markup tags with attributes and content. This approach of context modeling is often used to represent entities (user, device…) profiles using standards such as XML, CC/PP and UAprof. The evolution of the context modeling continues with the emergence of *graphical models* (UML, ORM...) and *Object Oriented Models*, whose strength is their structure. Finally, in the last few years, we could observe the development of research involving the semantic modeling of the notion of context, providing a more structured and rich description of the user's context through the emergence of *ontology based models*.

Numerous researches, on content adaptation [14] [27], service adaptation [26] [28] and information retrieval [8] were based on the semantic-based models describing context information. Such semantic modeling is based on the use of ontologies and ontology languages that support formal description and reasoning [28]. Ontology models are considered as the most suitable models for representing and reasoning on context information for several reasons: (i) they enable knowledge sharing in open dynamic systems; (ii) they allow an efficient reasoning on context information with well defined declarative semantics; and (iii) they enable service interoperability and collaborative networked services in a non ambiguous manner [26].

Among the numerous context models proposed in the literature, and mainly those proposing ontology-based models, we wish to highlight a small set of works described below. We consider them particularly significant and representative for the purpose of our research. We can organize them in two main "families": research on content adaptation (involving content presentation and retrieval) and research on Service-Oriented Architectures (SOA).

Regarding content adaptation, such works consider that the relevance of a given content depends on the context in which the user is consulting this content. In these works, context model is related to the notion of user's profiles. User's preferences or characteristics are often represented as context elements. Among these works, we would highlight the one proposed by Lemlouma and Layaïda [15]. These authors propose a context model based on CC/PP profiles in which information mainly related to the user's device capabilities and user's preferences is represented. By adopting a markup approach, Lemlouma and Layaïda [15] propose a structured model which is used in order to adapt content presentation of Web resources. However, capture (acquisition) and maintenance of such model depends mainly on the update of the corresponding profiles by the user.

Kirsch Pinheiro *et al.* [14] propose an object-oriented approach for structuring context elements and their relationships. Such a model is used to personalize the content provided by Web-based collaborative systems: supplied content is selected according user's context and preferences specific to this context. The originality of this model resides in proposing context elements that are related to collaborative aspects (user's role, activities, etc.) in addition to physical aspects (user's location and device). Nevertheless, capture and maintenance of these context elements are considered as external to the model: authors assume the existence of external components that observe the corresponding elements and feed the model. Besides, these authors [17] propose an ad hoc reasoning over this model through a set of similarity measures used to compare context elements and their relationships.

Even if previous context model can be seen as ontology, it remains expressed using an object-oriented approach. This is not the case of most recent context models, such as [8] [27]. Daoud *et al.* [8] works on information retrieval. They consider that by combining query's knowledge, user's context and search technology in a single framework, one can provide the most appropriate answer for a user's information needs. The context is represented as a set of user's interests and preferences. These authors [8] propose an approach based on learning techniques, in which user's interests are observed from his search history. Such interests are represented conceptually through ontology. These authors propose a context model including the user's personal characteristics, preferences, background, culture, system history, current location, etc., as well as the characteristics of the access device, of the network, etc. They define the user's profile in a multidimensional way, represented by the history of the information requests and the current information needs. Daoud *et al.* [8] build then the user's interest using a keyword-based representation and map such keyword-based representation into a concept hierarchy. Each concept has a weight reflecting the degree in which it represents the user's context at a given time. Afterwards, user's interests are updated by updating the search history representation.

A similar approach is proposed by Sutterer *et al.* [27]. These authors propose a user profile ontology in which they represent information about the user's profile, situation-dependent user's preferences, as well as his location and his activity. The user's profile is decomposed on profile subsets according to the user's context and dedicated to a specific (set of) service(s). For this, Sutterer *et al.* [27] use a matching process that matches the user's profile with these conditional profile subsets. These authors propose both UML and OWL to model service context ontology. This approach is used in the SPICE project (*Service Platform for Innovative Communication*) [13], which addresses the problem of designing, developing and putting into operation efficient and innovative mobile service creation/execution platforms for networks beyond 3G. It focuses mainly on multimodal delivery and user interface adaptation through the adaptation of the input and output modalities of a service according to the user's context and available resources.

SPICE project [13] is one of the numerous European projects [11][12] combining context-awareness and SOA. In the last few years, several projects proposed to adapt services supplied by a system according to the context in which these services are executed or called. In these works, the notion of context is used not only to personalize content supplied by the service (as in [27]), but also in order to adapt service composition or discovery. In such works, context models include often information about the user and about the involved services. Among the works proposing context models in SOA, we would underline [26] and [28].

Suraci *et al.* [26] propose a semantic modeling of services based on OWL-S. According to these authors, in order to provide context-aware services, one needs to consider both context inputs and outputs, in addition to functional ones, which may depend on contextual information. Context information is represented through an ontology-based model and it is integrated in the service description (by extending OWL-S description). Thus, Suraci *et al.* [26] aim at improving service modeling with context information (user information, service information and environment information). Such modeling focuses on adapting service composition to the user's requirements concerning context (device capabilities, user's location…). These authors consider that user should be able to specify contextual requirements corresponding to the service he is looking for (availability, location…), as well as to the context provided by the environment (wireless connection…). This work belongs to the European project DAIDALOS-II [11], which proposes a user-centric focus for building context-aware and mobile application based on SOA. It addresses a seamless pervasive access to content and services via heterogeneous networks that support user's preferences and context.

Another example of ontology-based context model is given by Toninelli *et al.*[28]. According to these authors, in pervasive scenarios, users require context-aware services that are tailored to their needs, current position, execution environments, etc. In order to reach this goal, service modeling should be improved, going further towards a semantic modeling that includes contextual information. These authors propose then a middleware supporting personalized, user-centric and semantic-based service discovery, in which user, device and service capabilities and requirements are represented. These entities (services, users and device) are modeled through a set of corresponding profiles. The service profile describes static and dynamic capabilities and requirements of the corresponding service. Thus, similarly to Suraci *et al.* [26], Toninelli *et al.* [28] propose an ontology-based context model, whose context elements are integrated in the service and user profiles. Such a semantic modeling contributes not only to handle problems related to service interoperability, but also to consider different aspects of the environment in which the service is executed.

Beyond content adaptation and SOA related works, other application domains have consider the notion of context. In the field of BPM (Business Process Management), Rosemann *et al.* [21] suggest an approach for integrating context into process models. They introduce a context framework that aims at extending the scope of business process modeling by incorporating and differentiating four layers of context, namely:

immediate, *internal*, *external* and *environmental* context. These layers are organized into concentric layers of an onion model, based on their proximity to the “core” business process.They propose a meta model to formalize the idea of how processes and their goals can be used to identify context that is relevant to the process. They provide also a basic procedure model on how to apply the framework for the identification and classification of context information.

Another work dealing with context reasoning in the BPM field is proposed by Balabko *et al*. [1]. The authors introduce a framework for business process modeling that makes contexts explicit in BP models. This framework is based on role modeling. In this framework, a system is modeled as a set of roles, in which each role is modeled in its own context. The concept of “role model” is used in order to represent the context in which the role is defined. The proposed role model includes the following main concepts: *object*, *role*, *activity* and *goal*. An object is an entity that can be modeled with a state (a set of attributes and relationships between them) and a behavior. An object plays roles by participating to the achievement of activities. A role is defined as an abstraction of the behavior of an object in a given context. Activities represent the collaborations between roles. Goals represent the post-conditions for roles (the state of an object may change, in order to specify these changes, pre and post conditions are used). Thus, the goal of the BP is defined as the set of goals for all defined collaborations (*i.e.* is the set of post-conditions of roles in a role model).

The works cited above represent a small but significant sample of works handling context models. They cover different approaches, from markup models to ontology-based ones, and use, from content adaptation (content presentation [15] and filtering [8][14]) to service adaptation (discovery [28], composition [26], etc.). In the next section, we present our general analysis of the literature and propose a framework which intents helping on understanding and proposing context models.

3. ANALYZING CONTEXT MODELS

Context-aware systems are systems particularly designed to react to context changes and to adapt in consequence their behavior. Such dynamic behavior can be observed in every work cited in previous section. It corresponds to the definition of such systems: context-aware systems are able to adapt their operations to the current context, aiming at increasing usability and effectiveness by taking environmental context into account [2]. These systems differ from each other on their behavior face to context changes. In other words, context-aware systems differ on what they adapt to context changes and how they do this.

We can see context-aware system, in a schematic way (Fig 1), as a system that supports some variability, the selection of a given variant being performed based on context information. In other terms, context information acts as an external element that guides variability internal to the context-aware systems. Such variability can be the adaptation of a supplied content by its selection, by adapting its presentation, etc., as well as the adaptation of the supplied service also by its selection, by its discovery or by adapting its composition. However, we cannot limit context-awareness to only content and service adaptation. Variability on context-aware systems can repose on a decision, an action that is taken under a given context. In any case, context information acts as a parameter that leads to the selection of the most appropriate variant and the adaptation process inherent to context-aware systems.

The dependence between observed context information and the behavior of a context-aware system can explain the large variety we could observe on context models. Definition of a context model depends on how we will exploit this model. Context-aware systems use context models in order to formalize and limit the notion of context. According to Mostéfaoui *et al.* [17], relevant information differs from a domain to another and depends on the effective use of this information. This fact can be observed on the works discussed in Section 2, in which different context elements (user profile, preferences, location, device, etc.) were observed for different purposes (personalize and adapt supplied content, discovery and configuration of services…). Moreover, this relevant context information set evolves with the application according to the user’s feedback, designer’s observations, or the availability of new technologies. Thus, the observed context elements as well as their use differ from a system to another, and consequently from a model to another, and it is often difficult to evaluate them. In this section, we propose a framework that analyzes and compares different context models. Such framework intends helping understanding of such models, and consequently the definition of new ones.

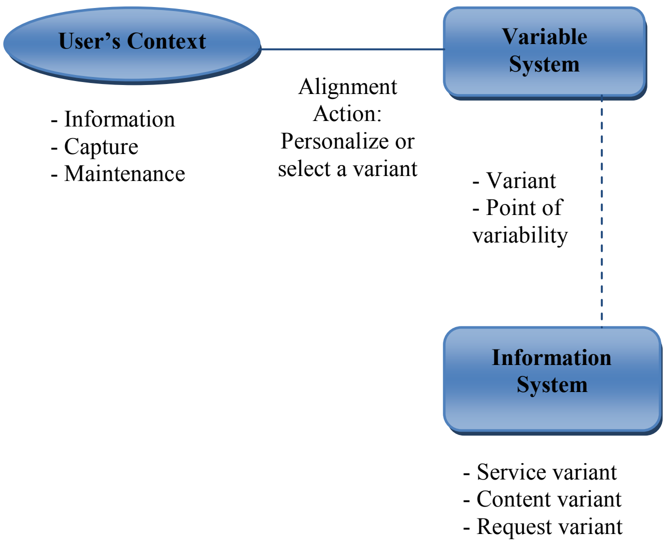

Fig 1. Schematic view of context-aware systems

The proposed framework, illustrated in Table 1, contains a set of evaluation criteria used to analyze context models. Such criteria are defined at the crossroad of the following issues:

- *Information*: What context information should be observed? This criterion determines, for an application, the type of information that could be observed and then used by the application. This information builds up the context that should be modeled.
- *Structure*: How this information is represented? Thus the structure presents the representation of the information. This criterion allows us to observe how structured the context representation is. It represents its degree of formalization.

- ***Capture***: What is the method used to obtain this information? For each application, in order to obtain the information about the context of use, we should have a strategy of capture that detects the actual information about the context and notifies a change in it.

- ***Maintenance***: How we can maintain this information up-to-date? The purpose of this criterion is to show how we can maintain the contextual information up-to-date and to define the strategy used for this.

- ***Reasoning***: Is it possible to interpret this information? This criterion represents the task of using context data in an intelligent way. It presents the techniques used to interpret the contextual information and to deduct knowledge.

- ***Action***: What are the actions taken based on the model? This criterion represents the type of actions used in a contextual situation. It shows what we can do with the contextual information.

For each criterion, we mention either keywords (*information* and *action*) or an indicator which represents a qualitative evaluation scale (*structure*, *capture*, *maintenance* and *reasoning*). In the first case, *information* criterion indicates context information that is observed in the presented model, whereas *action* criterion refers to the actions that can be taken considering context information (*i.e.* the purposes of observing context information).The *structure* criteria indicates how formal and structured the model is. Thus we indicate by a "++" whether information is highly structured, such as ontology-based models, by a "+" whether it is semi-structured, typically XML or object oriented models, or by "-" if it is no-structured (like on key-value model). The *capture* criterion refers to the automation degree of the context acquisition process. We indicate by a "++" whether information is captured periodically, by a "+" whether it responds to context change (following an event-based approach) or by "-" if it is manually. The *maintenance* criteria points out the strategy used to keep up-to-date context information. We indicate this criterion by a "++"

Author	Information	Structure	Capture	Maintenance	Reasoning	Action
Sutterer 2008 [27]	User profile, Situation-dependant user preferences	++	++	++	++	Service adaptation according to the situation-dependant user profile
Toninelli 2008 [28]	User profile, Device profile and Service profile	++	++	++	++	Discovery and configuration management services
Daoud 2007 [8]	User's interests and preferences	++	++	++	+	Personalized information retrieval process
Suraci 2007 [26]	User information, Service information and Environment Information	++	++	++	++	Registration and discovery of a service
Kirsch Pinheiro 2004 [14]	User's physical (location, device...) and collaborative (role, activity...) context	+	-	-	+	Content selection to mobile user in a group
Lemlouma 2004 [15]	User and environment information	+	-	-	+	Content adaptation for presentation on mobile devices
Rosemann 2007 [21]	Immediate (data...), internal (norms...), external (stakeholders strategies...) and environmental (weather...) context	-	-	-	-	Design of adaptive business process
Balabko 2003 [1]	State and behavior of a role	-	-	-	-	Context aware business process modeling

Table 1. Framework resuming main characteristics of discussed context models.

whether information is maintained automatically, by a "+" whether it is semi-automatically (on demand) or by "-" if it is manually. Finally the *reasoning* criterion indicates how we can exploit and reason about context information. We indicate by "++" whether it has a reasoning engine, by a "+" whether it has ad-hoc reasoning mechanism, or by a "-" if it has a weak reasoning mechanism.

Table 1 summarizes the analysis of the different context models described in Section 2 according to the criteria of the proposed framework. For example, Toninelli *et al*. [28] observe information about the user, device and service. These authors use an ontology expressed in OWL (++). In their middleware architecture, they use a *context manager* which is responsible for creating user's context when he initiates a discovery session, as well as for monitoring changes in the user's context and in external environment. The capture of the context information is automatic (++) and it is maintained at a pre-defined time intervals (++). However, they allow user to choose how he wants to maintain this information. They propose to maintain the context information upon any context change detection and upon explicit user request. These authors use an inference engine for the reasoning (++). They are based in a semantic matching algorithm using the *exact*, *plug in* and *subsume* notions. The action proposed by their AIDAS (*Adaptable Intelligent Discovery of context-Aware Services*) framework consists in a user-centric and semantic-based discovery of services for mobile users.

Rosemann *et al*. [21] observe contextual information and classify it into four categories. (i) The *immediate context* that captures essential elements to the understanding and execution of a business process (*e.g*. data, organizational resources such as organizational units and groups,, IT and related applications such as Web server and database system, etc.); (ii) The *internal context* which is related to the environment of an organization (*e.g*. the main internal stakeholders in an organization and their risk perceptions, communication and logistical infrastructures); (iii) The *external context* which includes elements that are part of an even wider system whose design and behaviour is beyond the control sphere of an organization (*e.g*. elements related to suppliers, competitors, investors and customers, etc.); and finally, (iv) the *environmental context* which includes factors that can be attributed to the macro-economical setting in which an organization operates (*e.g*. legislative regulations), weather conditions, etc.
In our opinion, the mentioned categorization is useful, nevertheless it is incomplete and contextual information is not clearly delimited. These authors [21] do not formalize the context representation (indicating a '-' in the Structure criterion). Furthermore, neither strategies for context capture and maintenance (-), nor reasoning techniques about context (-) are provided.
When considering these different context-aware systems, we notice that the notion of context usually adopted is user-centric. It is limited to some physical aspects, such as the user's location, preferences, profile, device… They consider the user individually, despite a few models [14][21] associating the notion of context with Groupware and organizational systems. However, the user is naturally involved in some cooperative process and needs to be aware of what is going on inside the group in order to build a sense of process and organization. Thus, the processes and organizational context should be considered as the physical context in order to evaluate what is relevant to a user, and then, to select the most appropriate variant for him. According to Dourish [10], "context – the organizational and the cultural context, as much as the physical context – plays a critical role in shaping action and also in providing people with the means to interpret and understand action". These users are engaged in a cooperative process and are particularly interested in information related to this.

Based on these observations, an extension of the traditional user-centric vision, presented is proposed in Fig 2. Through this extension, we consider that the notion of context and context-aware systems can be extended to other spheres, mainly process and organizations. In other words, we should consider user not only as an individual, but also as somebody who participates to several business process, which can influence his actions, and then his context. Such processes are performed inside one or more organizations, which influence the user's perception and behavior too.

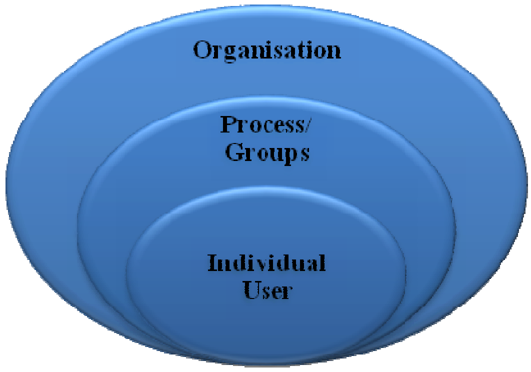

Fig. 2. Several spheres of context observation.

Thus, following the pattern illustrated by Fig 1, we argue that both context model and context-aware system can extend their contextual knowledge beyond simple individual user. The first level of this "context sphere" (Fig 2) proposes traditional user-centric vision, in which context-aware systems and their context models consider only individual user. However, the second level extends contextual knowledge to the processes users participate. Context-aware systems on this level use this extended knowledge about users and processes for adaptation purposes. Similarly, the third level goes further, considering the organizations as a whole. We believe that, when the application domain involves cooperation and multi-user interaction, context models and context-aware systems should evolve from simple user sphere to process and organization ones. Actually, context notion in application domains such as Business Processes (BP), in which the notion of process and organization play an important role, remain almost unexplored and no dedicated method is proposed yet.

Thus, in order to illustrate the proposed framework and how we can evolve to process sphere, we propose in the next section a context model particularly designed for Business Process modeling community.

4. CONTEXT MODEL FOR BUSINESS PROCESS MODELING: CM4BP

4.1 Business Process Variability and Context Information

A business process (BP) is defined as a set of one or more linked activities that collectively realise a business objective or policy goal, normally within the context of an organisational structure which defines functional roles and relationships [29]. Among the concepts used to model business processes, one of the most important is the “role” [4][18]. The concept of *role* specifies the responsibility of each actor (a user) and reflects the organisational structure. It improves the understanding of the way responsibilities are achieved in the organisation. Commonly, responsibilities and tasks are assigned to roles, which are allocated to actors (the users). However, within an organization, actors can be brought to change their behaviour following the situation they face. Actually, the actors’ behaviour may change according to the context in which the organization and the actors find themselves. Roles played by actors as well as tasks and responsibilities assigned to roles may vary following the context. Moreover, customers’ expectations can vary following the context in which these expectations are formulated. As well, dynamic context changes and unexpected events cause divergence between the predefined process models and their current instances. Hence, *context knowledge* becomes an essential resource to adapt the behavior of BPs, since a conventional BP model may fit customers’ expectations in a given context and not in another one. Although this evident relation between context and the way business processes are executed, process models remain disconnected from relevant context knowledge [21].

Many researches [4][18][20][21] stress the importance of modeling flexible and adequate business processes. Existing approaches dealing with business process flexibility focused on intrinsic ways of adopting or modifying business processes after a need for process change arises. They capture only the reactive part of process flexibility and ignore the stimulus for change, *i.e.* the context. We consider that the ability to integrate context knowledge allows adapting business process model according to this context, ensuring the variability and the flexibility of it. For instance, the assignment of a role to an actor can vary according to the context in which this process is executed: if the process is running out of time, a given role can be assigned to an expert actor instead of a novice one.

However, only a few works in BP literature [20][21][23] have considered context-awareness in business process. Despite these works, there is a lack of approaches that support adaptability according to the contextual requirements of business process models and instances. We also observe a lack of formalisms in representing context concepts and managing them, *i.e.* a lack of context models really appropriate to BP modeling.

In order to use efficiently the contextual information in business process rules, the *context related knowledge* should be formally defined through a context model. Based on the framework presented in Section 3, we propose here an ontology-based context model focusing BP modeling and instantiation. However, before introducing this model, we present a role-based business process meta-model, proposed in [22]. This meta-model represents the main concepts related to business processes, which can be affected by the notion of context, formalized by the model in Section 4.3.

4.2 Role based Business Process Meta Model

We introduced in [22] a Role-based Business Process Meta Model, called RBPM, which represents main concepts related to BPs (see Fig 3). We consider that a BP can be first analysed in terms of *roles* played by actors and the corresponding functions. The role either represents competency to realise particular functions (*e.g.* an engineer) or embodies authority and responsibility (*e.g.* project supervisor). A business goal is reached by executing a BP which includes several roles and the functions that actors playing these roles should perform. As shown in Fig 3, actors belong to organisational units and are assigned to appropriate roles based on their responsibilities and qualifications. The concept of *function* serves as a link between roles and operations: a function is defined as a collection of operational goals satisfied by achieving operations. Conventional role-based approaches define processes in such manner that a given operation should be executed by a specific role. We argue that context related knowledge concerns BP elements (*e.g.* actors) and has an impact on assignment relations, that is, on the relationships between entities expressed in the meta-model (*e.g.* a role can be assigned to an actor under a given context and to a different actor under another one; a function can be held by several roles in several contexts with regard to the current situation and the flexibility purposes).

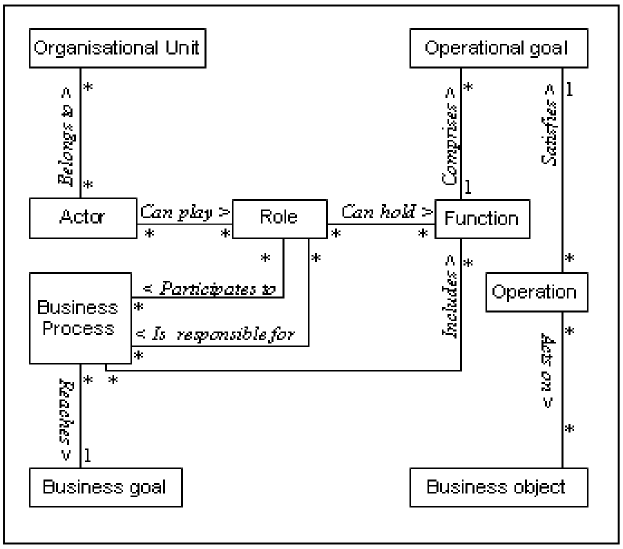

Fig. 3. The meta-model of RBPM

Actually, all the assignment relationships expressed in the meta-model can be considered as context-aware. For instance, regarding the assignment relation *can play*, actors are assigned to roles according to their capability in a particular context. Similarly, the assignment relationship *can hold* is commonly defined by conventional role-based approaches as a given operation that should be executed by one specific role. However, this is not always possible at the instance level. If all actors playing a given role are unavailable, a function should be performed by a different role. Context information can contribute answering the question: "In which context a function can be held by a given role?". Let us consider, for example, an actor named *Steve* that belongs to the *loan handling service*. He plays the role "*Loan_assistant*" and has a *good experience* in the domain of loan handling. As a consequence, one may consider that he can be assigned to the role "*Loan_manager*" if and only if all actors which can play the role "*Loan_manager*" are *unavailable*.

4.3 The CM4BP

Based on the framework proposed on Section 3, and on the influence context information may have on BP modeling, we present in this section a context model called CM4BP (*Context Model for Business Process*) focusing this domain. Through this model (originally proposed on [23]), we illustrate how the proposed framework can be used in order to develop context models on different application domains in which this notion can be relevant.

Following this framework, the first question to be considered is "what context information should be observed?", corresponding to the *information* criterion. As pointed out by Section 3, context information is quite related to the application domain, BP modeling in our case. Thus, we assume that *any information reflecting changing circumstances during the modeling and the execution of a BP* can be considered as contextual information (duration, experience, availability, device, time, and location). In order to identify such information, one should first understand the organization, second, identify the business processes that are currently performed on it, and third identify the internal and external dependencies between elements of the organization (*e.g.* actors, BPs).

Regarding the criterion *structure* (cf. Section 3), we adopt an ontology **(++)** based approach in order to represent the contextual information and to use it adequately. The main reasons motivating the use of an ontology is the possibility of reasoning about it (for example, deducting new context knowledge from known ones). In such ontology (represented in Fig 4), the ***entities*** describe the non-functional features: *Process, Task, Actor, Resource, Organizational Unit, Role* and *Business object*. Each of them is addressed by context elements, which have values that are directly measurable. A ***context element*** is an atomic feature making explicit the context knowledge and characterizing the entities. Its value might change dynamically (e.g. *date*) or vary from different instances of the same entity (e.g. *location*, *duration*).

Entities are associated with the context elements through the association ***has***, meaning that an entity is characterized by one or more context elements. Fig 4 resumes some examples of this association (more details in [23]). Among these, we can underline the entity *actor*, which represents the users. This entity can be characterized (association *char_a*), among others, by the ***context elements*** *experience*, *achievement history*, *availability* and *physical elements* (*location*, *time*, *device*). Another example, the entity *process* is characterized by *duration* and *time to finish,* whereas the entity *resource* is characterized (association *char_res*) by the elements *availability* and *location*.

Concerning the criteria capture and maintenance, it will be extended progressively during our research **(-)**.

Concerning the criterion *reasoning* introduced in the Section 3, we propose using a first order predicate named *CRK* **(++)** with four arguments: *Attribute Subject*, *Link* and *Value*. *Attribute* and *Subject* denote respectively elements and properties expressed using the proposed ontology. *Link* relates the subject and the value. The link can be preposition (*e.g. In, At*), a comparison operator (*e.g.* =, >), or an adverb (*e.g. near*). Examples for context predicate CRK include:

- CRK (Experience, Georges, >, 5 years)
- CRK (Location, Georges, In, 90 rue Tolbiac – 75013 Paris) → CRK(Role, Georges, =, Trainee)

The values of the *Subject* and *Value* arguments depend on the *Attribute* argument. Thus, if the *Attribute* is '*Location*', then *Subject* can be an actor or a business object, by observing the relation "*has*" of the proposed ontology.

Since reasoning is based on first-order logic, it is possible to apply Boolean operations and quantifications over CRK predicates, allowing the expression of more complex predicates. For example, the predicate $\exists x,\ x \in ACTORS,\ CRK(Experience,\ x,\ >,\ 5\ years)$ is true if and only if $CRK(Experience,\ x,\ >,\ 5\ years)$ is true for at least one value of x belonging to the set *ACTORS*. The predicate $\forall x,\ x \in ACT,\ ACT \subseteq ACTORS,\ CRK(Experience,\ x,\ >,\ 5\ years)$ refers to all actors whose experience is higher than five years. By constructing such complex predicates, we can reason on entities and context elements represented in the ontology and deduce new knowledge based on it.

Thus, we can resume our CM4BP, according to the framework proposed in Section 3, by defining the different criteria proposed, as illustrated in Table2.

Information	Context element (duration, experience, availability, achievement history, …) Physical element (location, time, device, …) Entity (process, actor, role, …)
Structure	++ Ontology
Capture	- to be extended progressively during our research
Maintenance	- to be extended progressively during our research
Reasoning	++ First Order Logic
Action	Business Process Management – *Process enactment*

Table 2. Analysis of the CM4BP according to the proposed framework

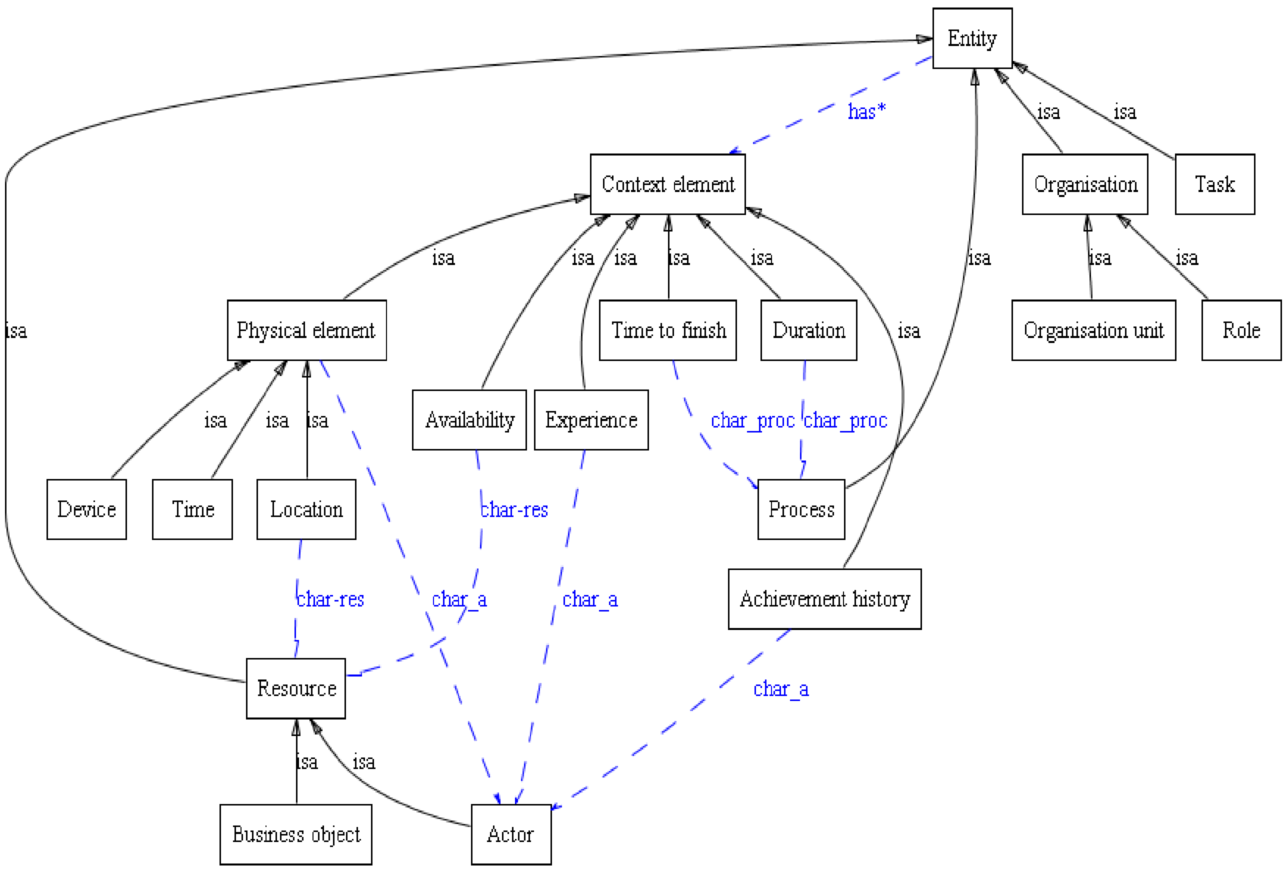

Fig. 4. Ontology for Context Modeling.

In this paper, we discussed only a small part of the proposed context model, focusing on a general analysis of the model, illustrating how the framework proposed in Section 3 could contribute to the definition this context model. However, it is worth noting that the proposed ontology is not exhaustive and will be extended progressively during our research.

5. CONCLUSIONS AND PERSPECTIVES

In this paper, we discussed the semantic representation of the important notion of context by reviewing several context models proposed in different application domains. According to this, we proposed a framework that analyzes and compares different context models. The goal of such a framework is to help understanding and analyzing context models, and consequently the definition of new ones. This framework relies on the fact that relevant information differs from a domain to another and depends on the effective use of this information. Based on this framework, we consider in this paper the Business Process modeling as a particular application domain, in which the notion of context remains unexplored. This domain considers the user in his process and organization, and it needs for flexibility and adaptability. In this paper, we proposed a novel vision of the user-centric context models by presenting the user not as an individual alone, but as individual within a complex environment (process, organization). The proposal of an ontology-based context model focusing on this particular domain demonstrates this vision.

As perspectives, we are particularly interested on evolving the proposed context model, going further into the exploration of this model for the variability of BPs, as well as into the analysis of context elements and reasoning on them. Finally, we are currently investigating the exploration of the proposed framework on Service Oriented Architectures, notably for the personalization of supplied services.

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